Development of an aberration corrected PEEM at the ALS

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PEEM3 Project team

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Modeling the resolution

-Resolution evaluated by mapping secondary electron angle and energy distribution through fields

-electron distribution from sample in (θ,φ,E)

-Distribution in $N(\theta)=\cos(\theta)$

-Uniform distribution in φ

-kinetic energy distribution $N(E)=E/(E+w_f)^4$

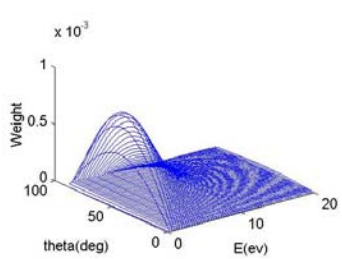
-->Weighted "macro-particle"

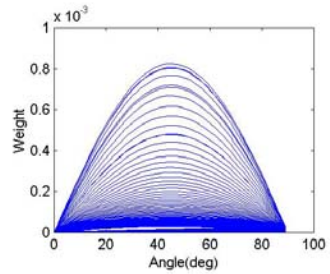
$N(\theta,\varphi,E)=\cos(\theta)\sin(\theta)E/(E+wf)^4$

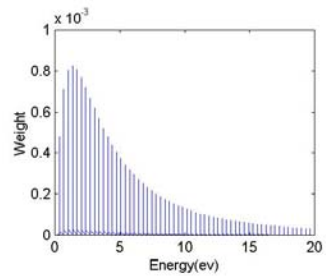
-all order ray tracing technique used

-Detailed model check with SMART, PEEM2, charge ring +DA map method

-Modulation Transfer Function calculated by FFT method

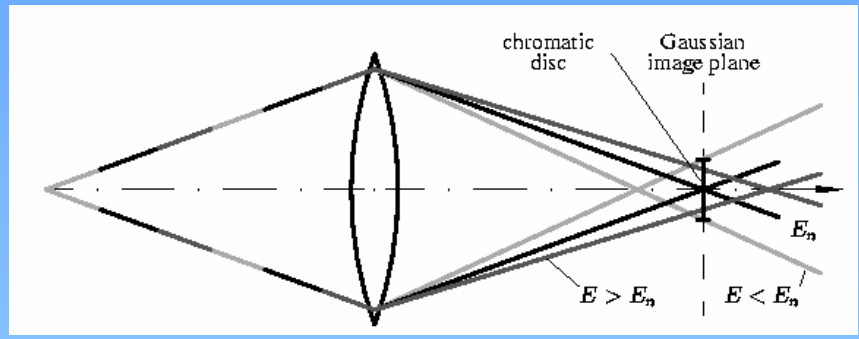




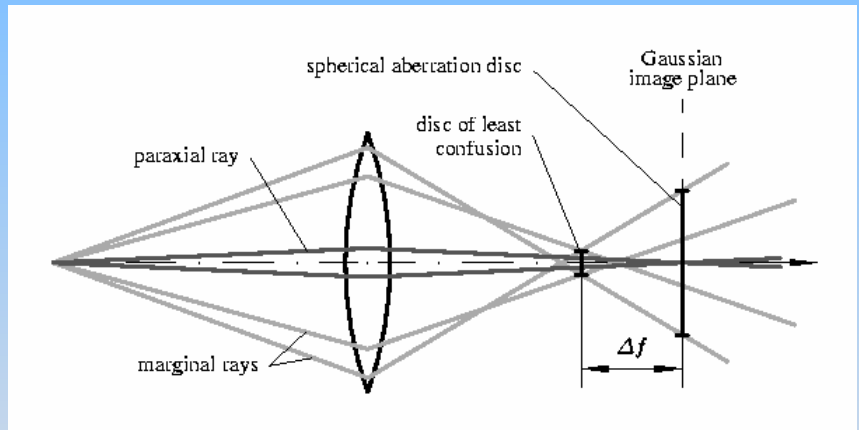


Aberration existed in electron lens just like in light optics lens

Chromatic aberration



Spherical aberration

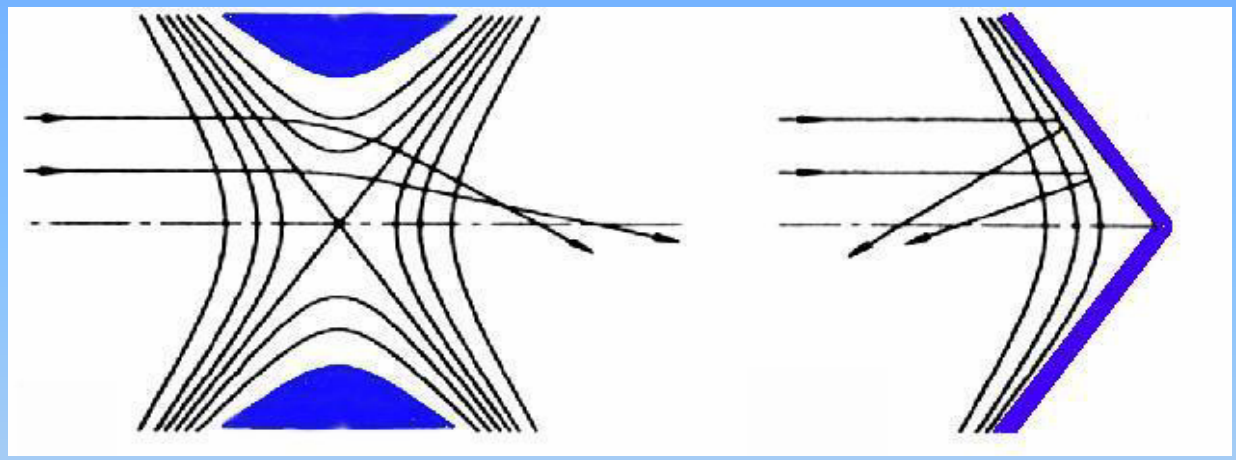


$$r = \sqrt{(C_s \sin^3 \alpha)^2 + (C_c \delta \sin \alpha)^2 + (0.61\lambda / \sin \alpha)^2}$$

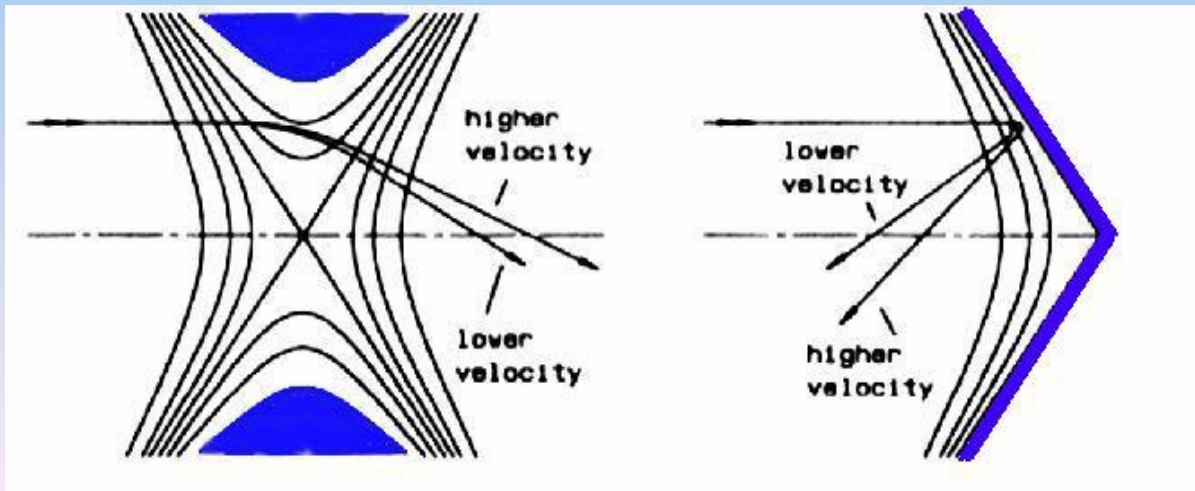
These aberrations limit PEEM resolution

Electron mirror can compensate the aberration of electron lens

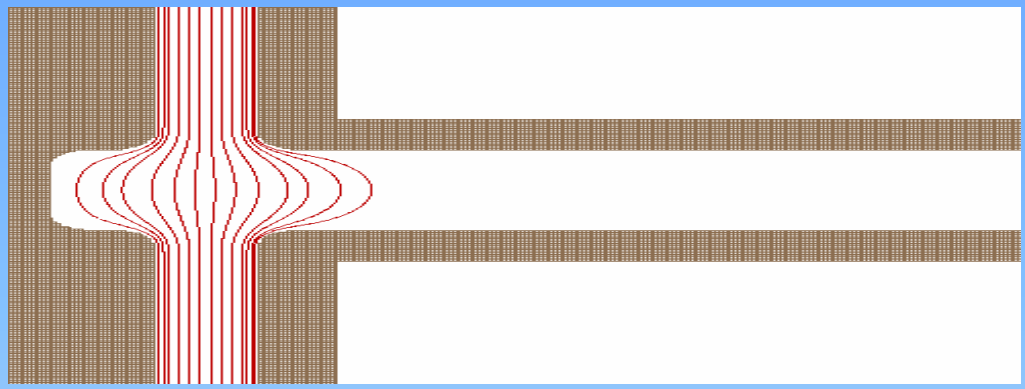
Spherical aberrations



Chromatic aberrations



Model checking with other theory

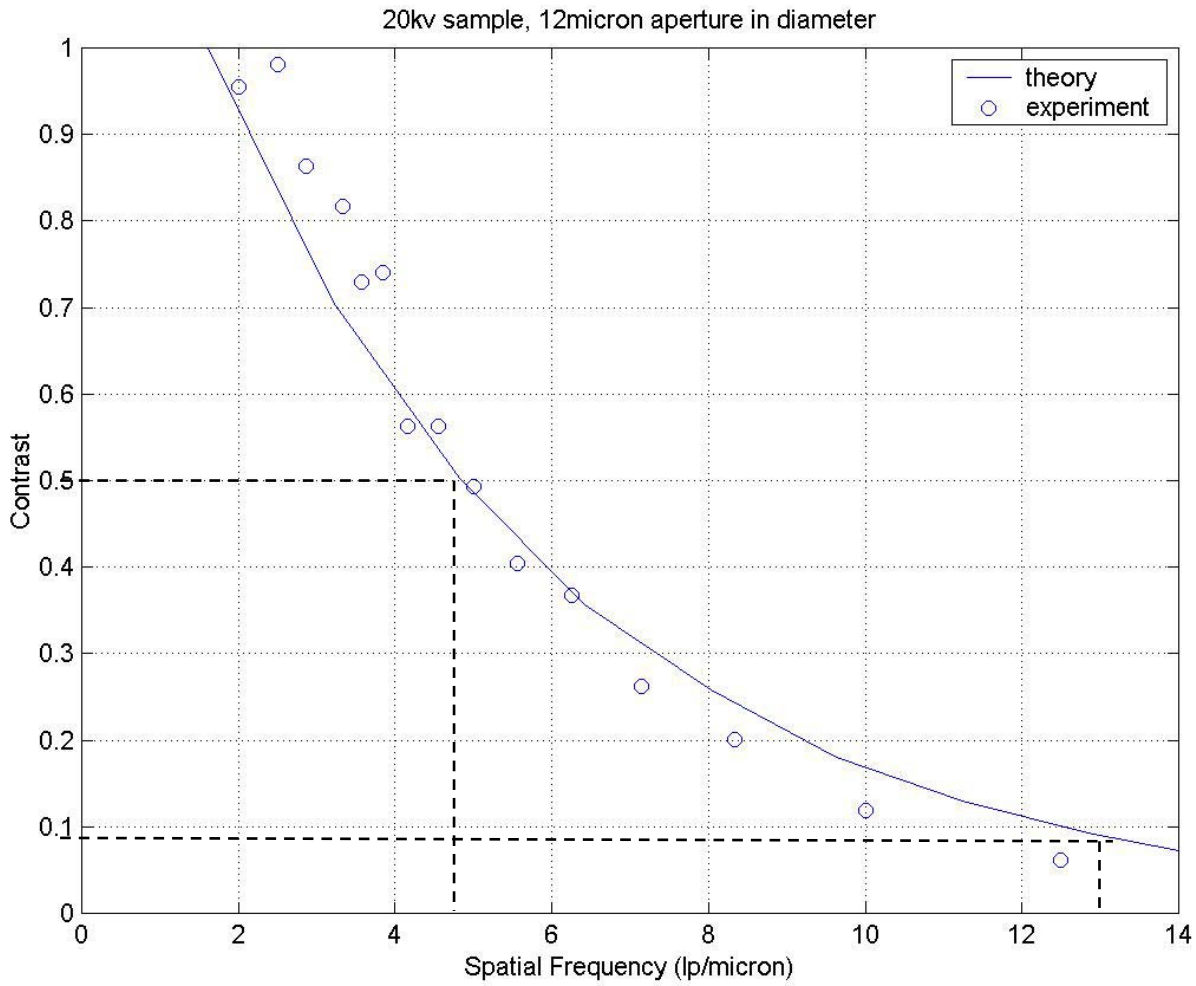


$$r = \theta\Delta f + \theta^3 C_3 + \theta^5 C_5 - \kappa\theta C_c - \kappa\theta^3 C_{3c} + \kappa^2\theta C_{cc}$$

Aberration coefficients comparison

	Δf	Cc	C3	C5	C3c	Ccc
Smart	2.10^{-9}	-9.8173m	-539,71m	-904640m	-3269.8m	-5.4317m
Our	$1.03.10^{-6}$	-9.829m	-539.84 m	-913725 m	-3268.5m	-5.387m
Diff	~0	0.12%	0.02%	1%	0.04%	0.8%

Model check with experiment: PEEM2 Resolution



It begins with near unity modulation at low frequency and gradually becomes lower towards higher frequencies.

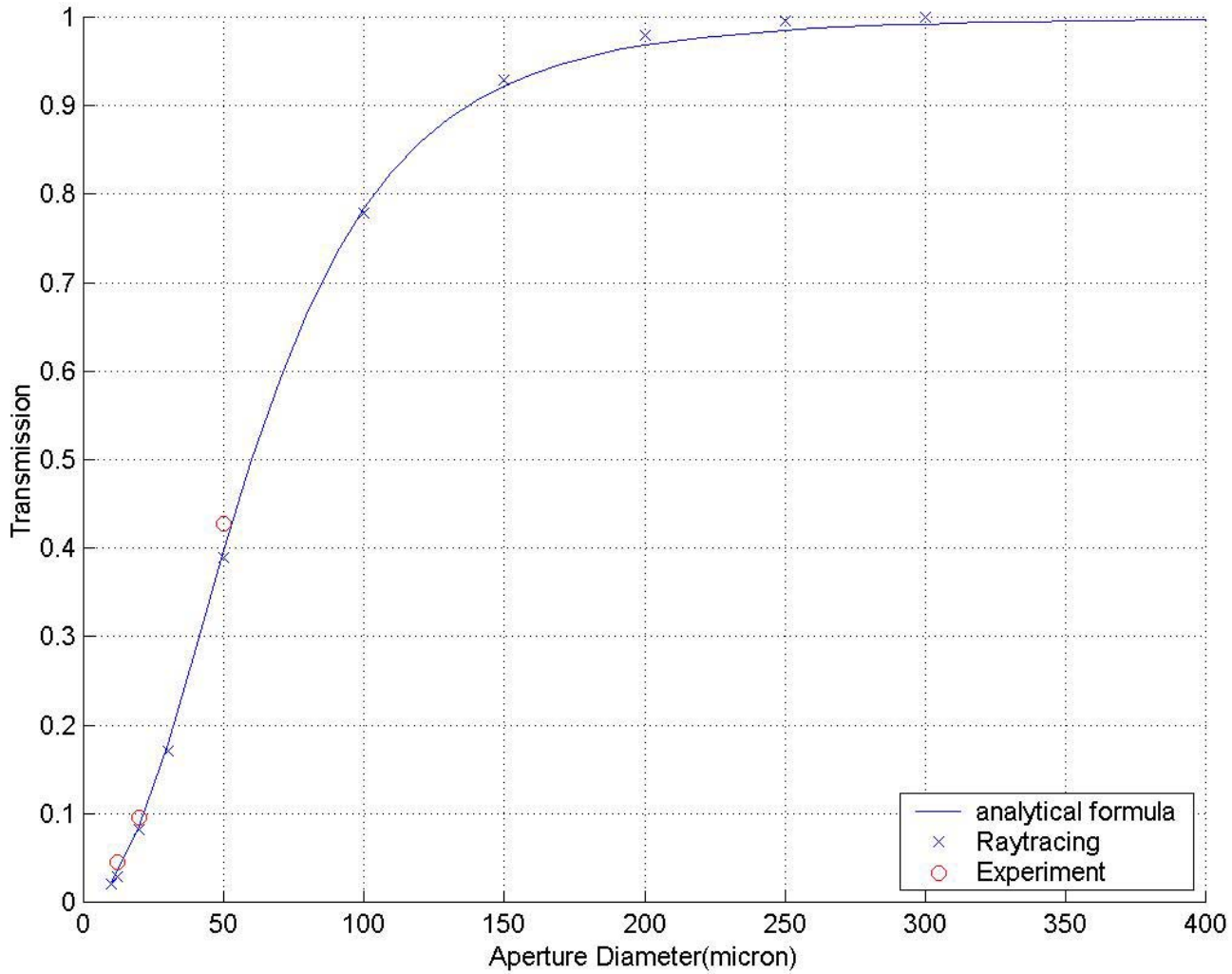
Contrast 1 means the image detail is perfectly maintained, while zero modulation transfer shows that it was completely lost, or not "seen" in the imaging process. Values between 0-1 indicate varying degrees of spatial details preserved.

50% resolution definition: 100nm

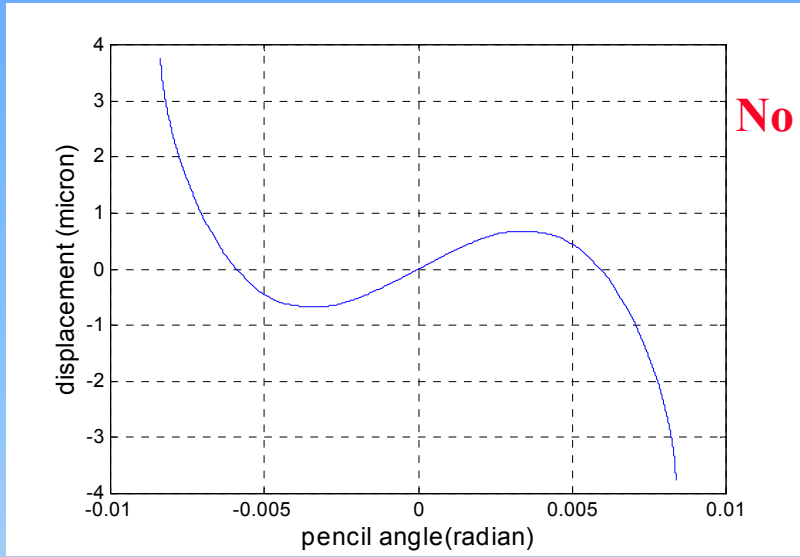
9% Rayleigh limit resolution: 38nm

MTF provides a continuum of unique ranking by which to judge a microscope's resolution performance.

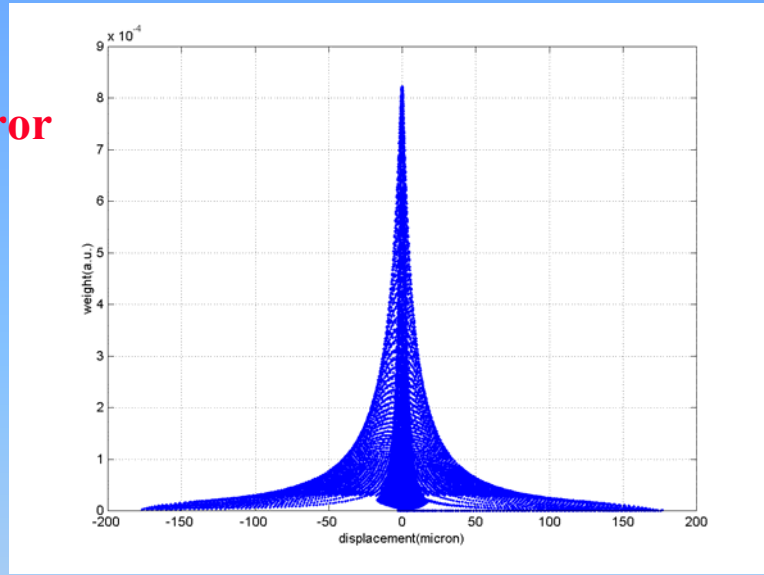
Model checking with experiment: PEEM2 Transmission

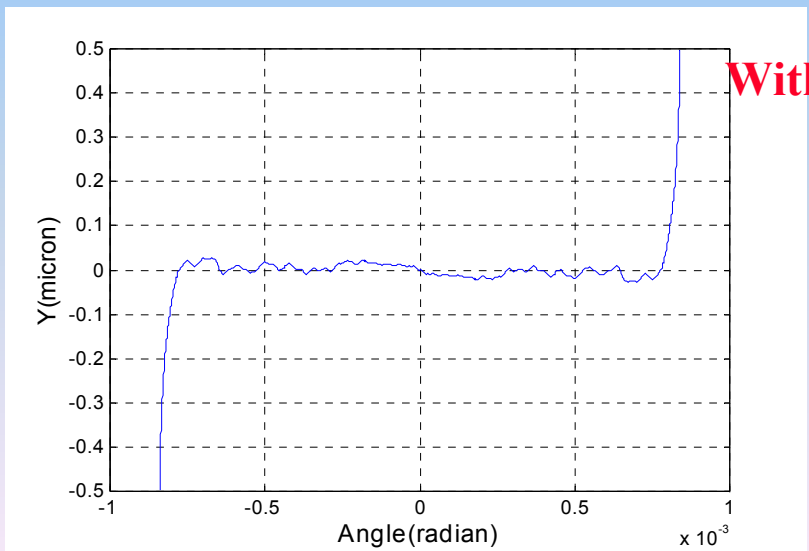


Aberration correction

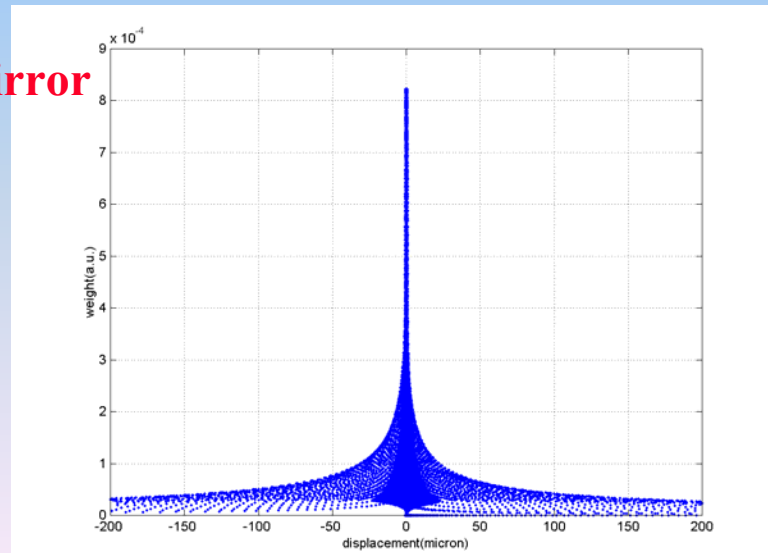


No mirror

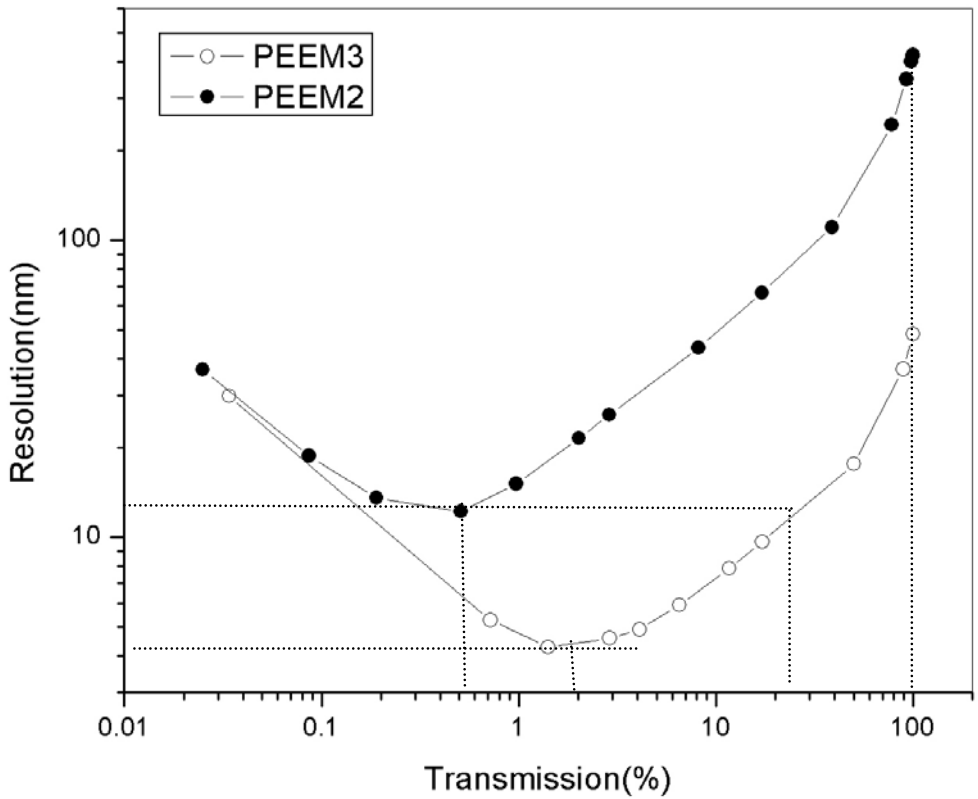




With mirror



Resolution for PEEM3

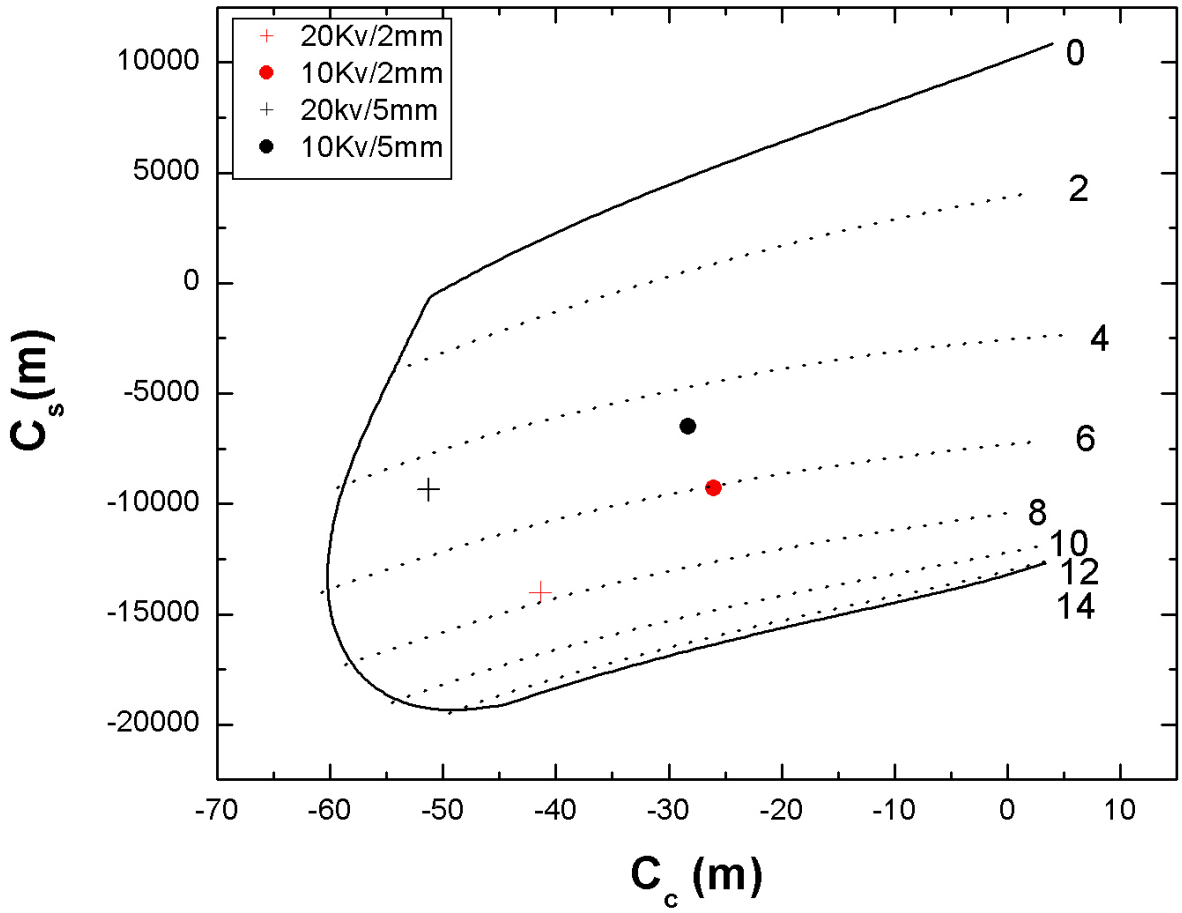


-All order ray trace results

-Diffraction limit included

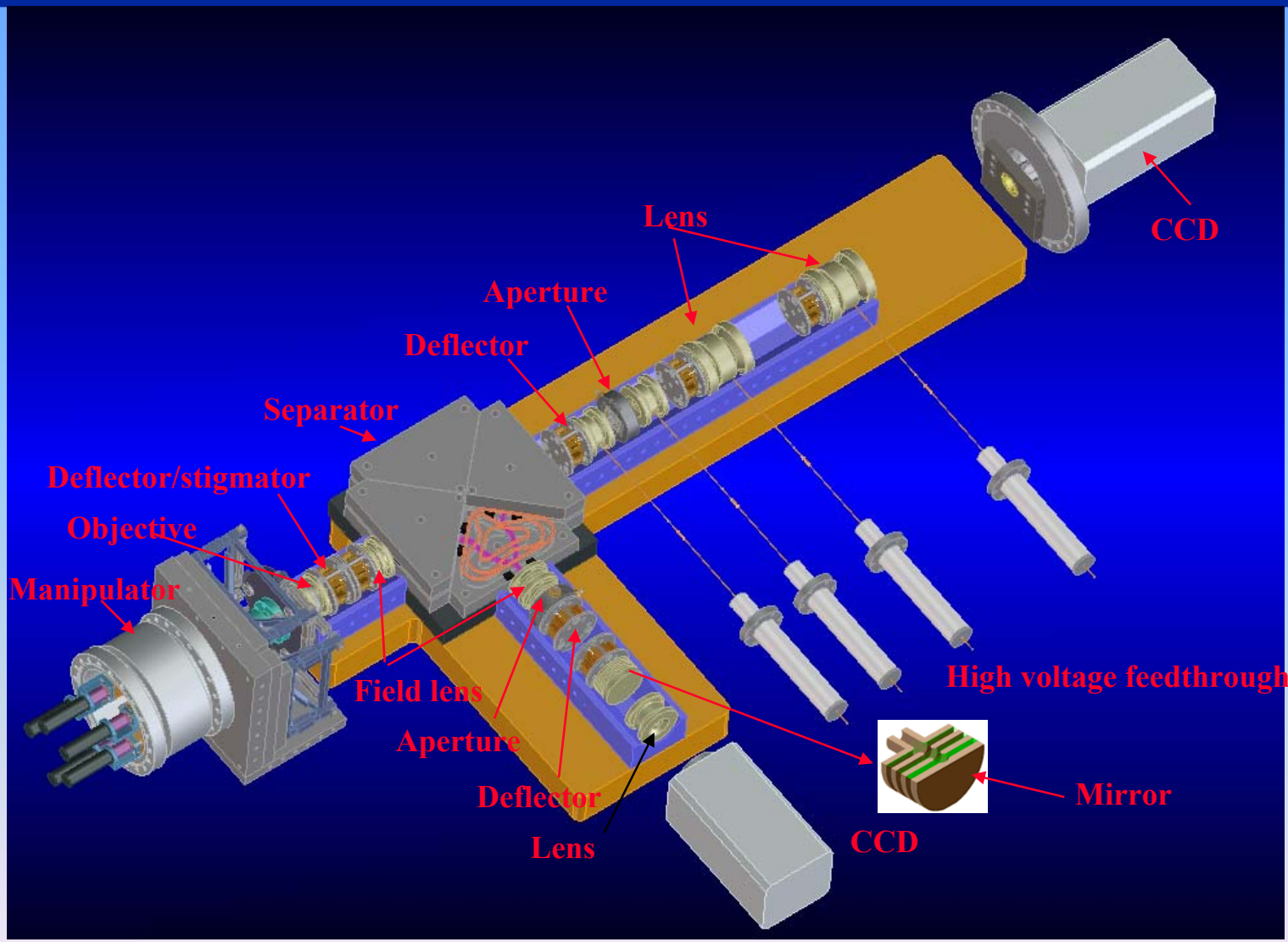
-Both resolution and Transmission improved

Aberration range



Tetrode mirror covers the whole range for different operation conditions

PEEM3 layout



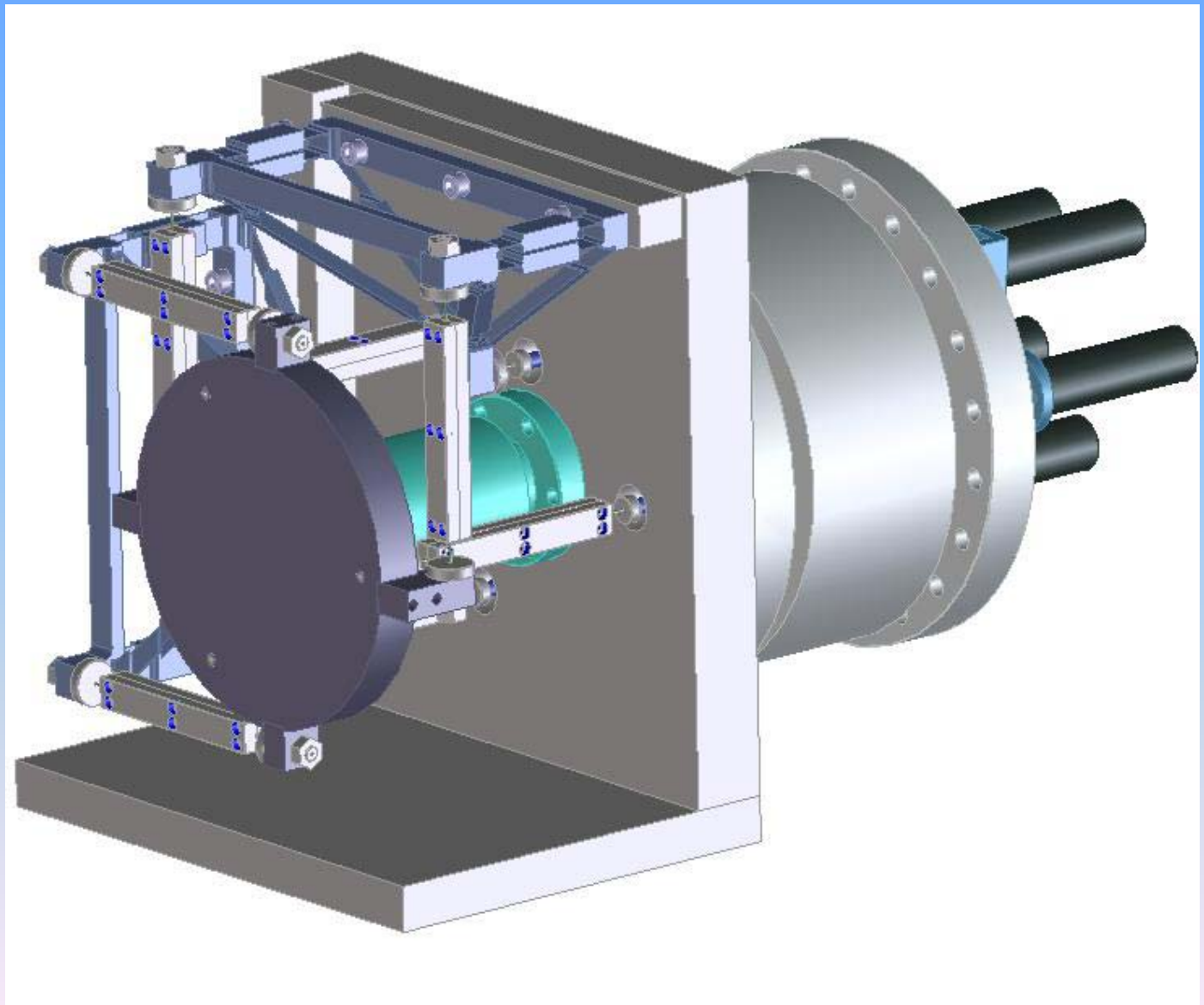
-high stability

-separator is in vacuum

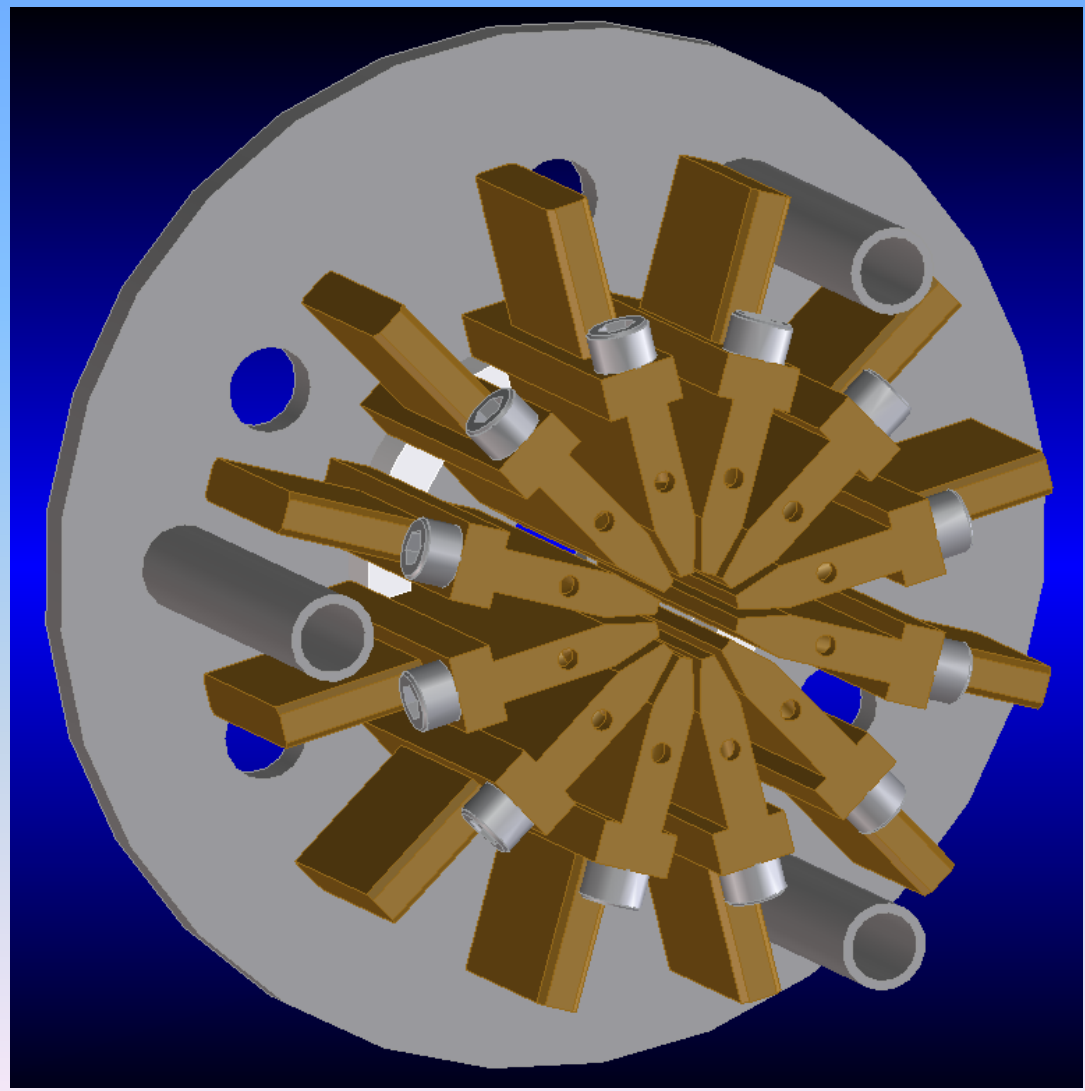
-Two CCD

Three knobs for three variable: Cs Cc, f

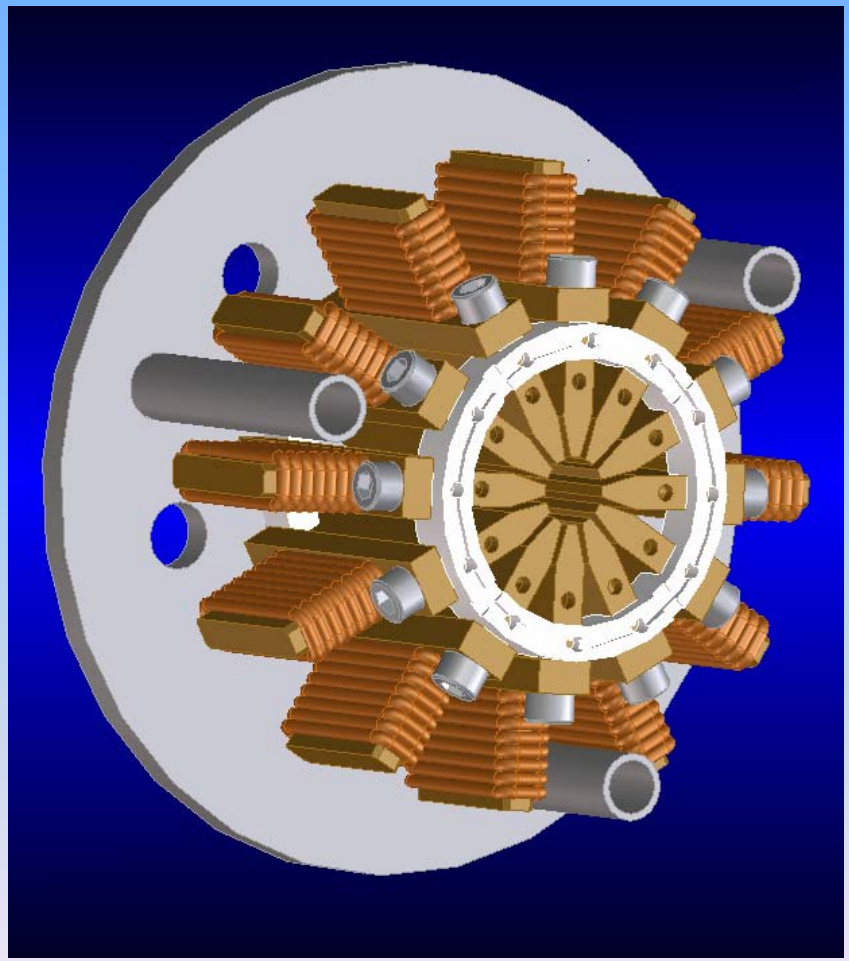
Manipulator

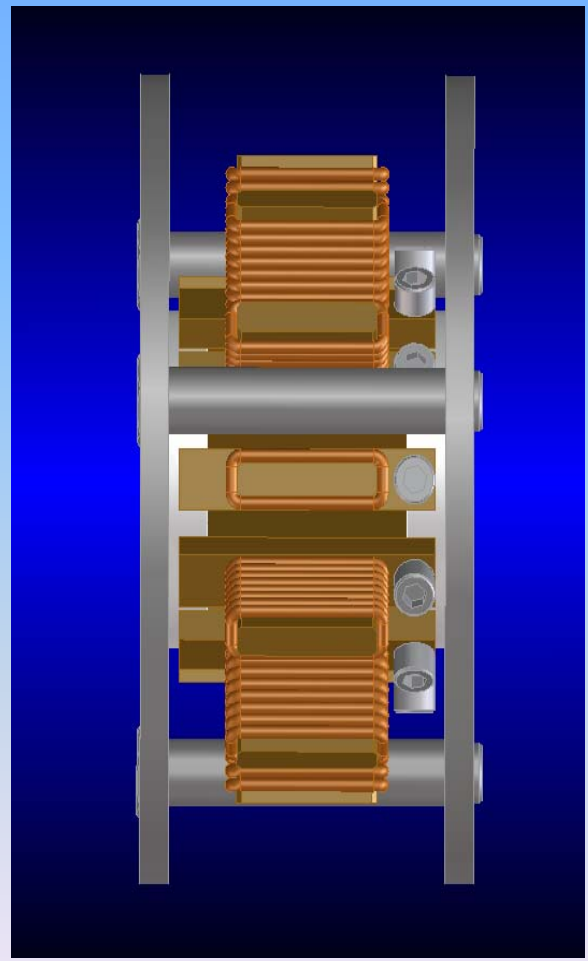


Dodecapole stigmator



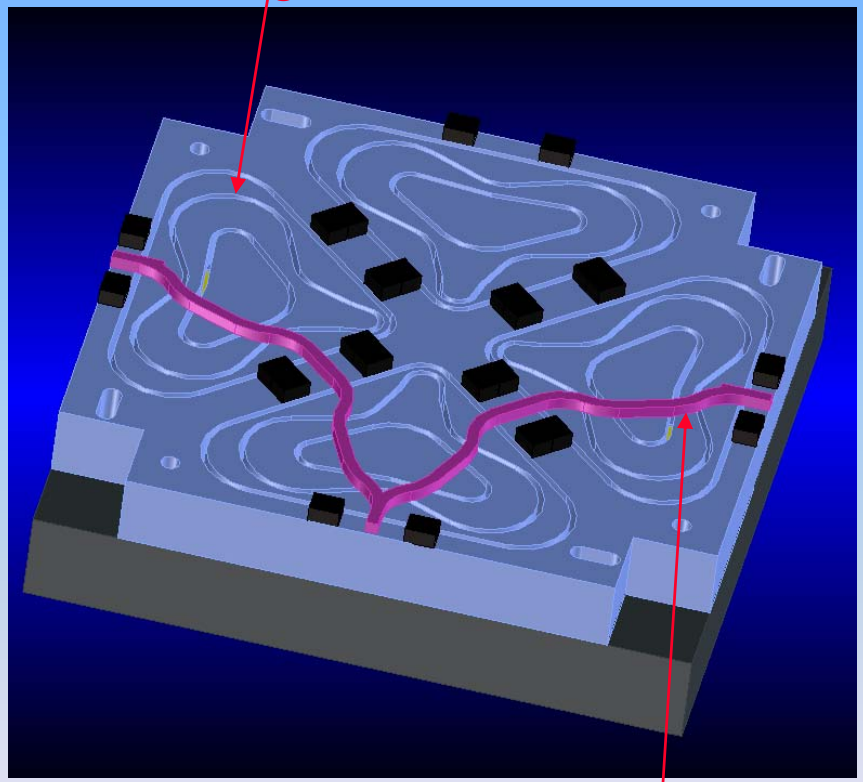
Electromagnetic dodecapole deflector

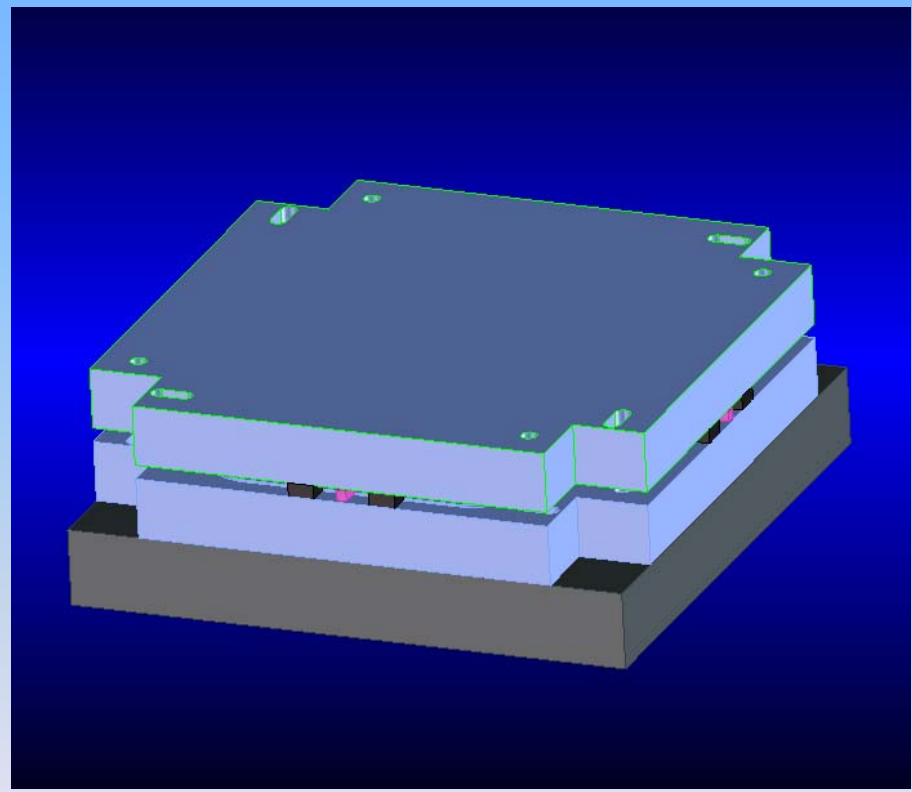




3D engineering modeling of Magnetic separator

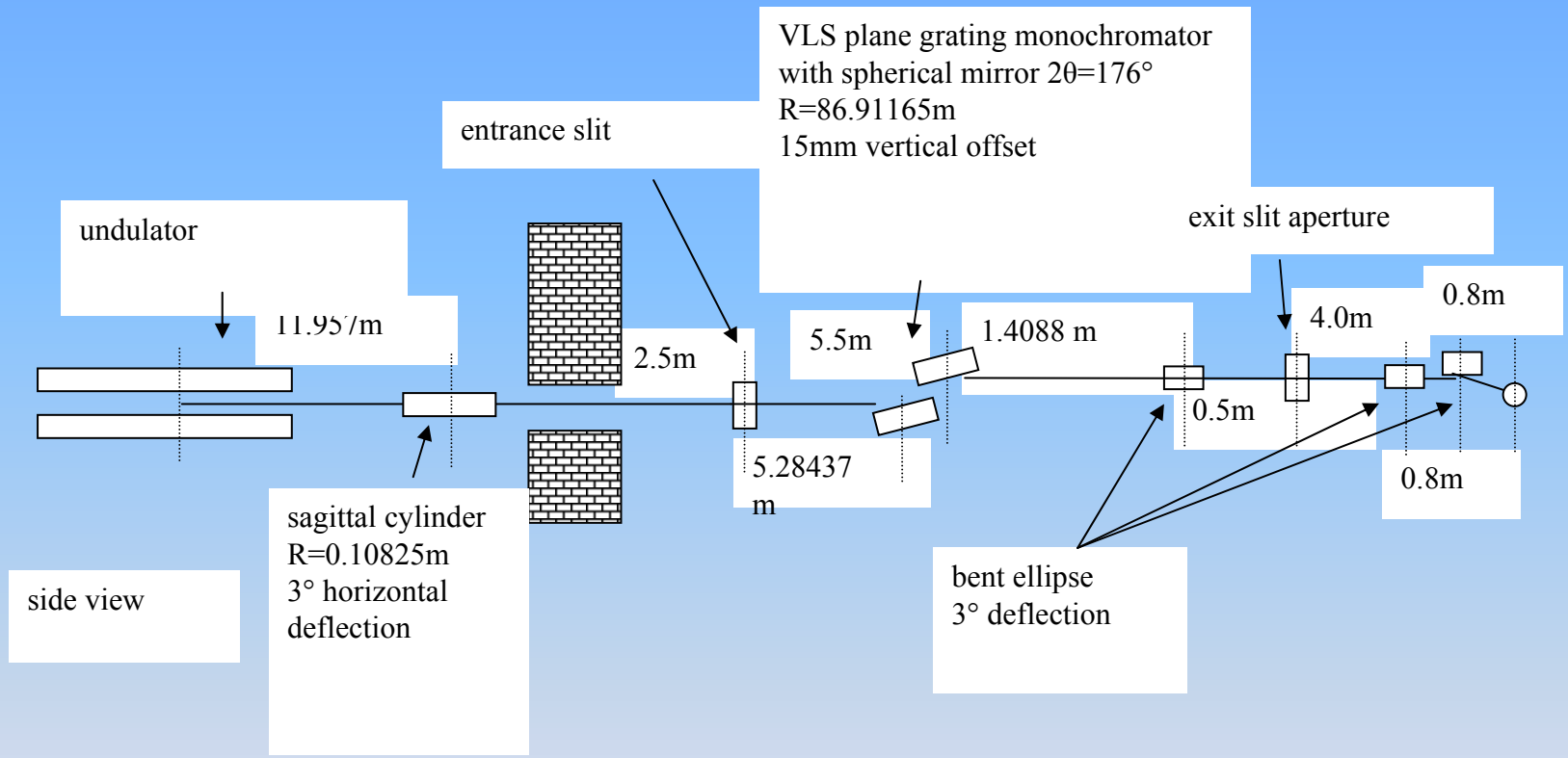
Groove/ coil, water cooling through the wire



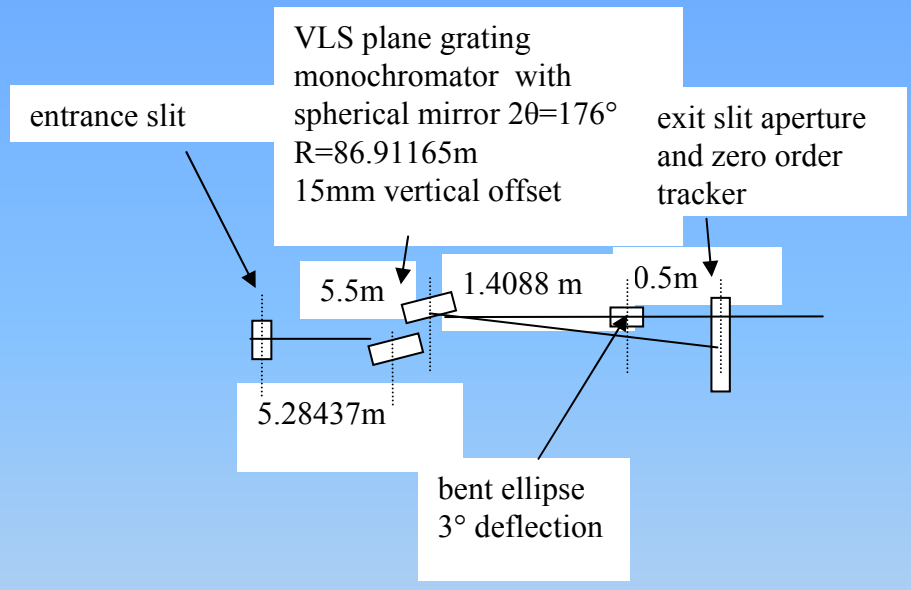


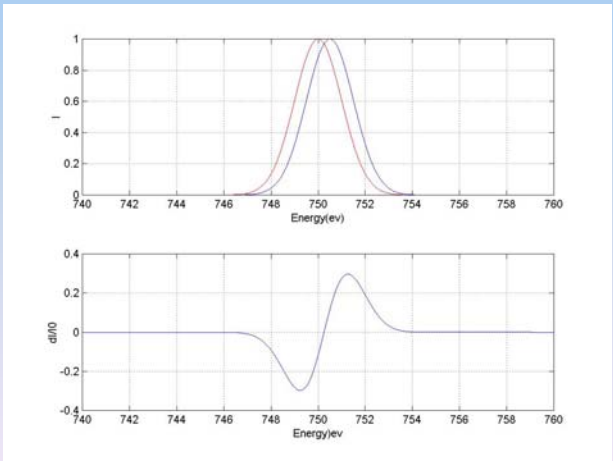
Electron trajectory

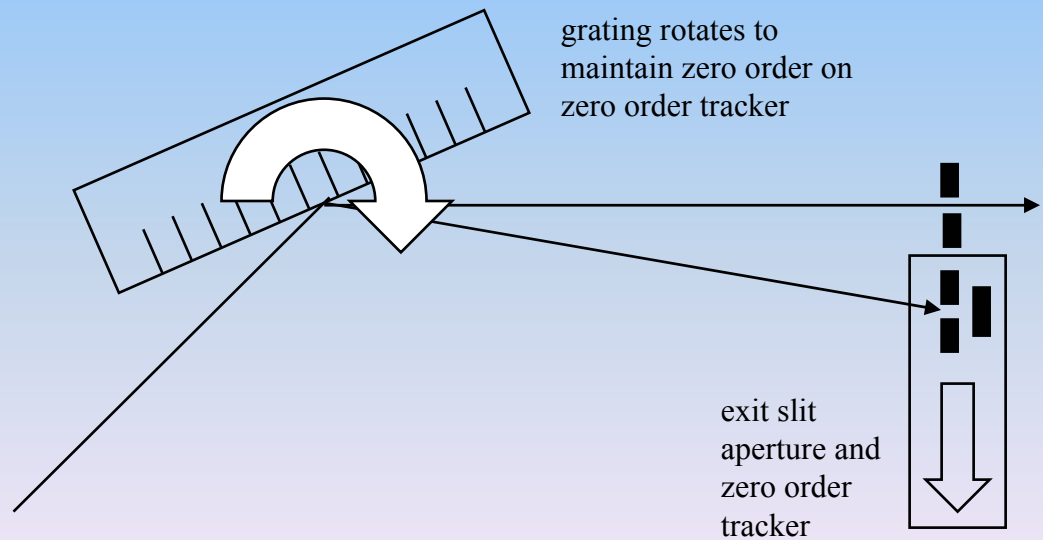
PEEM3 beamline



Zero order tracking for constant energy scale







10^{-4}, stability <0.165mev

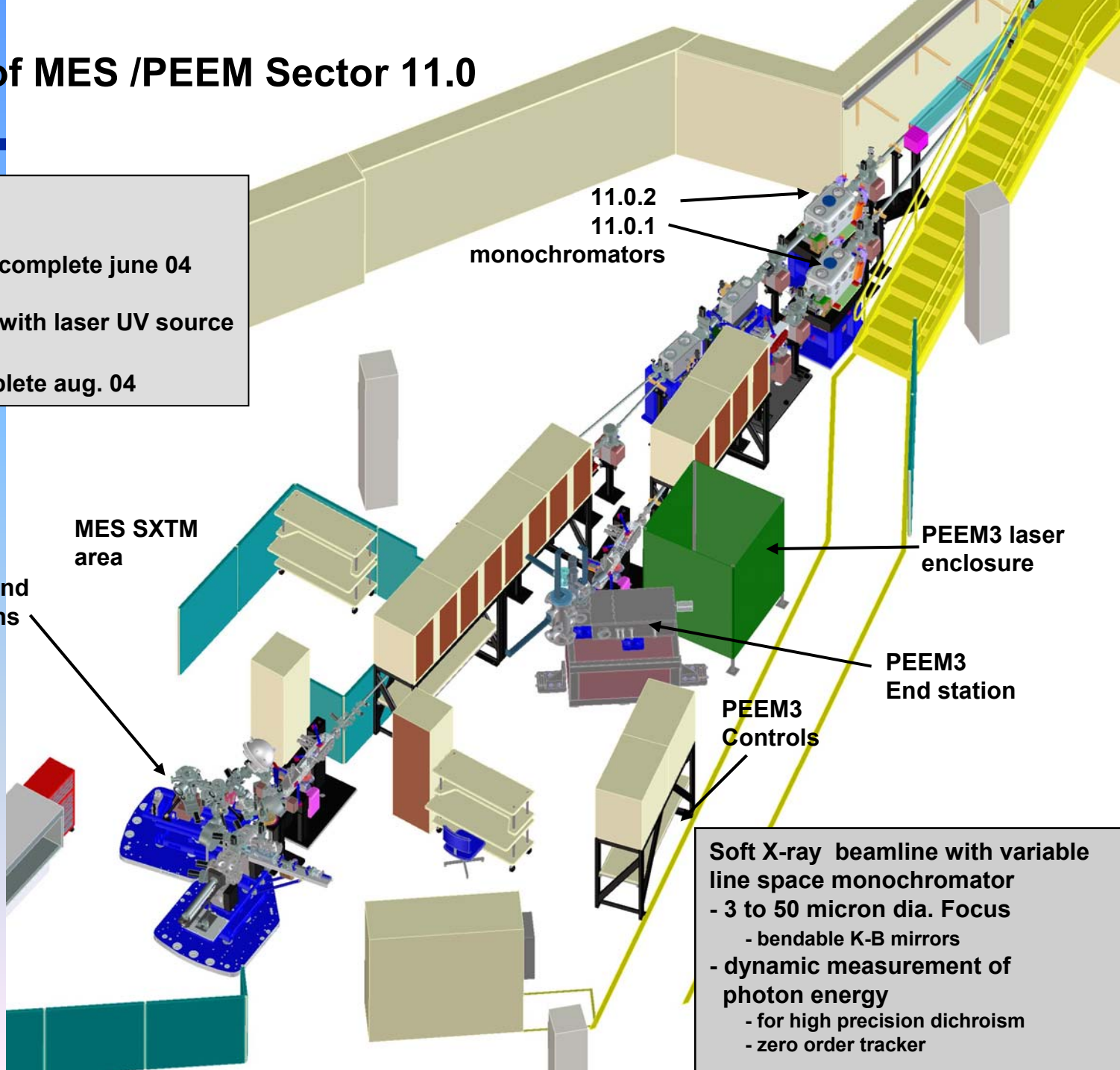
Floor Layout of MES /PEEM Sector 11.0

Schedule

-microscope systems complete june 04

- commissioning with laser UV source

- EPU / beamline complete aug. 04

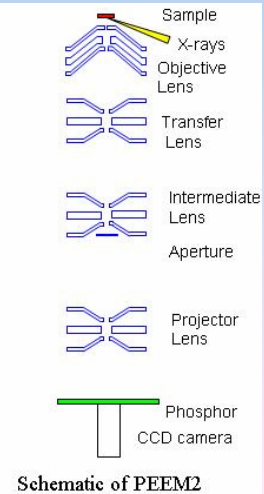


Soft X-ray beamline with variable line space monochromator

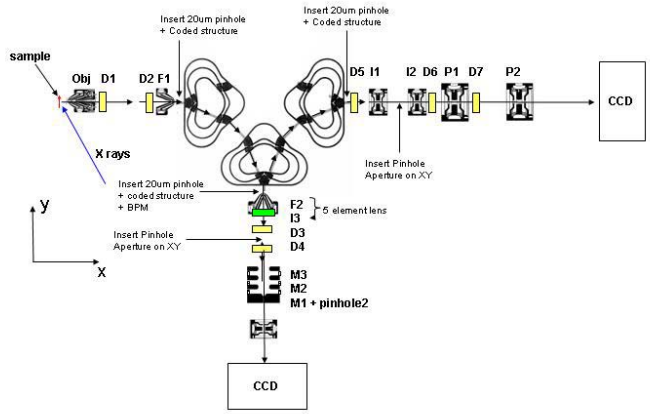
- 3 to 50 micron dia. Focus
  - bendable K-B mirrors
- dynamic measurement of photon energy
  - for high precision dichroism
  - zero order tracker

PEEM2 - PEEM3 comparison

	PEEM2	PEEM3
Optics	Electrostatic lens	Electrostatic lens Electrostatic mirror Magnetic separator
Diagnostic	last image	movable pinhole, alignment PEEM
corrector	Octopole	Electromagnetic dodacapole
Resolution	20nm	5nm
Transmission @50nm	5%	>90%
Beamline	Bending 7.3.1.1	EPU 11.0.2
Relative Flux density	1	>1000



Schematic of PEEM2



Schematic of PEEM3